MINING AND MILLING METHODS AND COSTS, TRI-STATE ZINC, INC., JO DAVIESS COUNTY, ILL.

BY W. A. COLE

* * * * * * * * * **Information Circular 7780**

UNITED STATES DEPARTMENT OF THE INTERIOR
Fred A. Seaton, Secretary
BUREAU OF MINES
Marling J. Ankeny, Director

Work on manuscript completed March 1956. The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is made: "Reprinted from Bureau of Mines Information Circular 7780."

April 1957

MINING AND MILLING METHODS AND COSTS, TRI-STATE ZINC, INC., JO DAVIESS COUNTY, ILL.

by

W. A. Cole[1]

CONTENTS

	Page
Summary and introduction	1
Acknowledgments	1
History of mine	4
Description of deposits	5
Geology	5
Type of deposit	7
Physical characteristics	7
Exploration	8
Development	9
Mining (stoping)	9
Room-and-pillar mining	9
Mine organization	11
Drilling and blasting	11
Ore handling in stope	12
Underground transportation	12
Summary - equipment, power, and supplies	14

---

[1] Mine examination and exploration engineer, Bureau of Mines, Region V, Minneapolis, Minn.

Information Circular 7780

Original from THE OHIO STATE UNIVERSITY

CONTENTS (Con.)

Page

Ventilation 14

Mine drainage 15

Appendix I - Costs and performance 15

    Summary of costs 15

    Performance data 17

Appendix II - Milling 18

ILLUSTRATIONS

Fig.

1. Surface map showing outline of ore bodies, Gray mine, Jo Daviess County, Ill. 2

2. Bautsch mine map 3

3. Generalized stratigraphic section of the Upper Mississippi Valley lead-zinc district 6

4. Sequence of steps in room-and-pillar open stope 10

5. Standard 38-hole V-cut round 13

6. Flowsheet, Gray mine 19

TABLES

1. Gray mine production total to June 30, 1955 5

2. Summary of costs (in dollars) 15

3. Output per drill shift and per man-shift.................. 17

4. Summary of costs in units of labor, power, and supplies .. 18

SUMMARY AND INTRODUCTION

Underground mining methods at the Gray mine of Tri-State Zinc, Inc., are of special interest because of the low unit costs achieved through use of jumbos and loading equipment mounted on crawler-type tracks and of diesel trucks that haul from the stoping areas to the mill through inclined adits.

The operating company, Tri-State Zinc, Inc., is a wholly owned subsidiary of Gold Fields American Development Co., Ltd., the latter being the American branch of New Consolidated Gold Fields, Ltd., a British-owned company.

The Gray mine is in Jo Daviess County, Ill., 5-1/2 miles southeast of Galena and near the southern edge of the Upper Mississippi Valley district. The mine comprises a group of deposits designated by property ownership and other names (fig. 1). Present mining operations are conducted at both ends of the major deposit, the Bautsch ore body (fig. 2). A system of open stopes with pillar support has been followed in mining this deposit, first by breast stoping and later by a method locally called shrinkage stoping. One of the latter stopes was open for inspection in the southeastern section of the Bautsch deposit; however, such stoping has been temporarily discontinued, and broken ore in the stope is utilized as a roadway to breast-stoping operations to the east.

Stopes that attain a maximum height of 125 feet are maintained in a safe condition by carrying on drilling, blasting, and roof-trimming operations from the top of the broken ore piles as the work progresses. Broken ore is bulldozed over the brink of the pile and loaded from the stope floor by an electric shovel.

ACKNOWLEDGMENTS

The author is deeply grateful to V. C. Allen, manager, Tri-State Zinc, Inc., for supplying and permitting the use of production, performance, and cost figures covering fiscal year for 1955 operations at the Gray mine, together with a mine map and flowsheet of the Gray mill.

Appreciation is expressed for the courtesies extended and assistance given in a review of the report by V. C. Allen, manager, and Paul Herbert, geologist, Tri-State Zinc, Inc.

Operations at this mine have been described previously by V. C. Allen in the technical press, and acknowledgment is made to the American Institute of Mining and Metallurgical Engineers,2/ Institution of Mining and Metallurgy, London, England,3/ and Mining World.4/

2/ Allen, V. C., Diesel Truck Haulage Through Inclined Adit: Trans. AIME, Mining Engineering, June 1951.

3/ Allen, V. C., Mechanization at an Upper Mississippi Valley Zinc-Lead Mine: Trans. Inst. Min. and Met. (London, England), vol. 62, 1952-53, part 6.

4/ Mining World, How Tri-State Zinc Continues to Operate With Low Metal Prices: Vol. 17, No. 3, March 1955, pp. 44-48; How Tri-State Zinc's Efficient Management Lowers Milling Costs: Vol. 17, No. 4, April 1955, pp. 48-50.

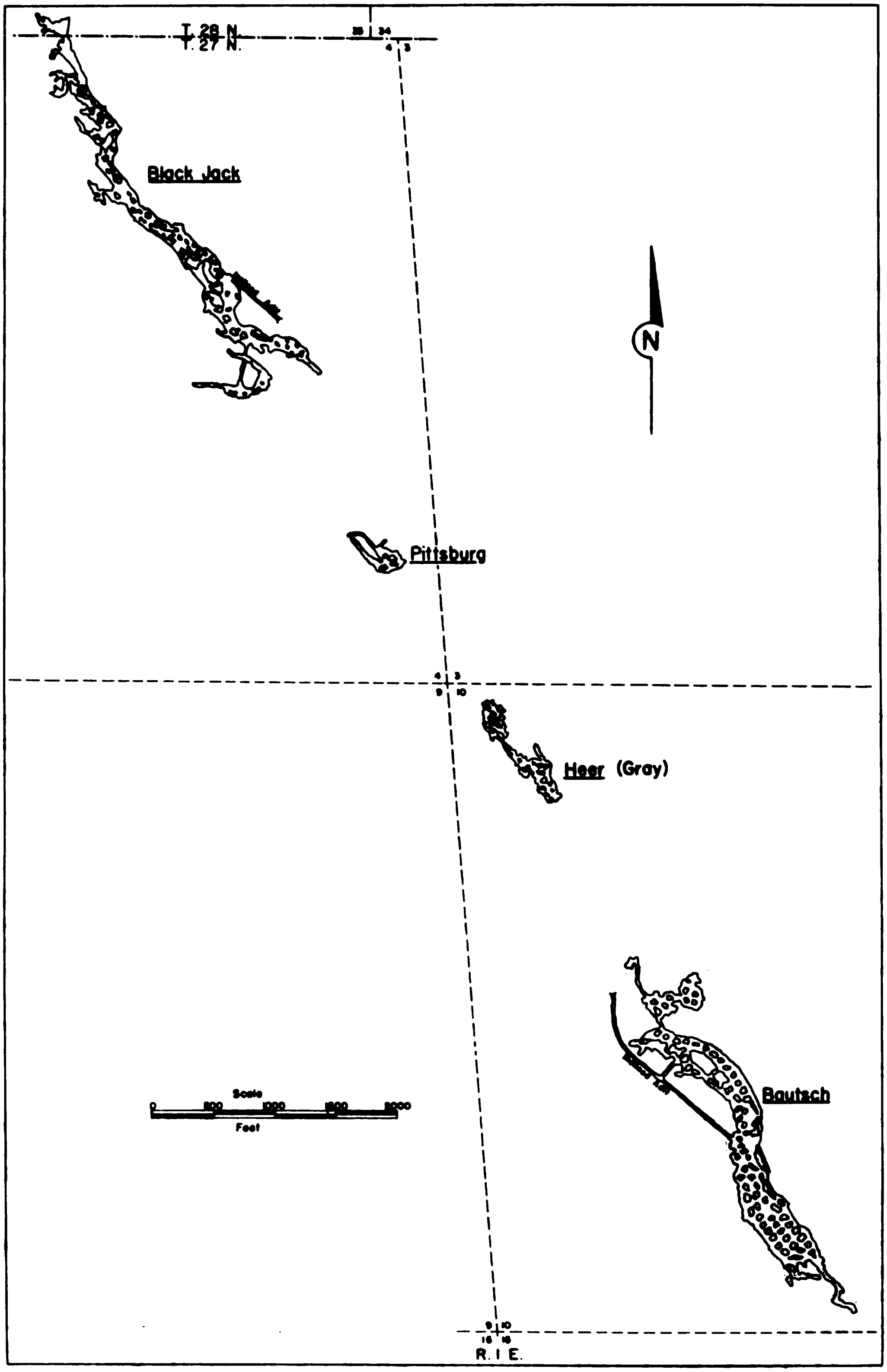

Figure 1. - Surface map showing outline of ore bodies, Gray mine, Jo Daviess County, Ill.

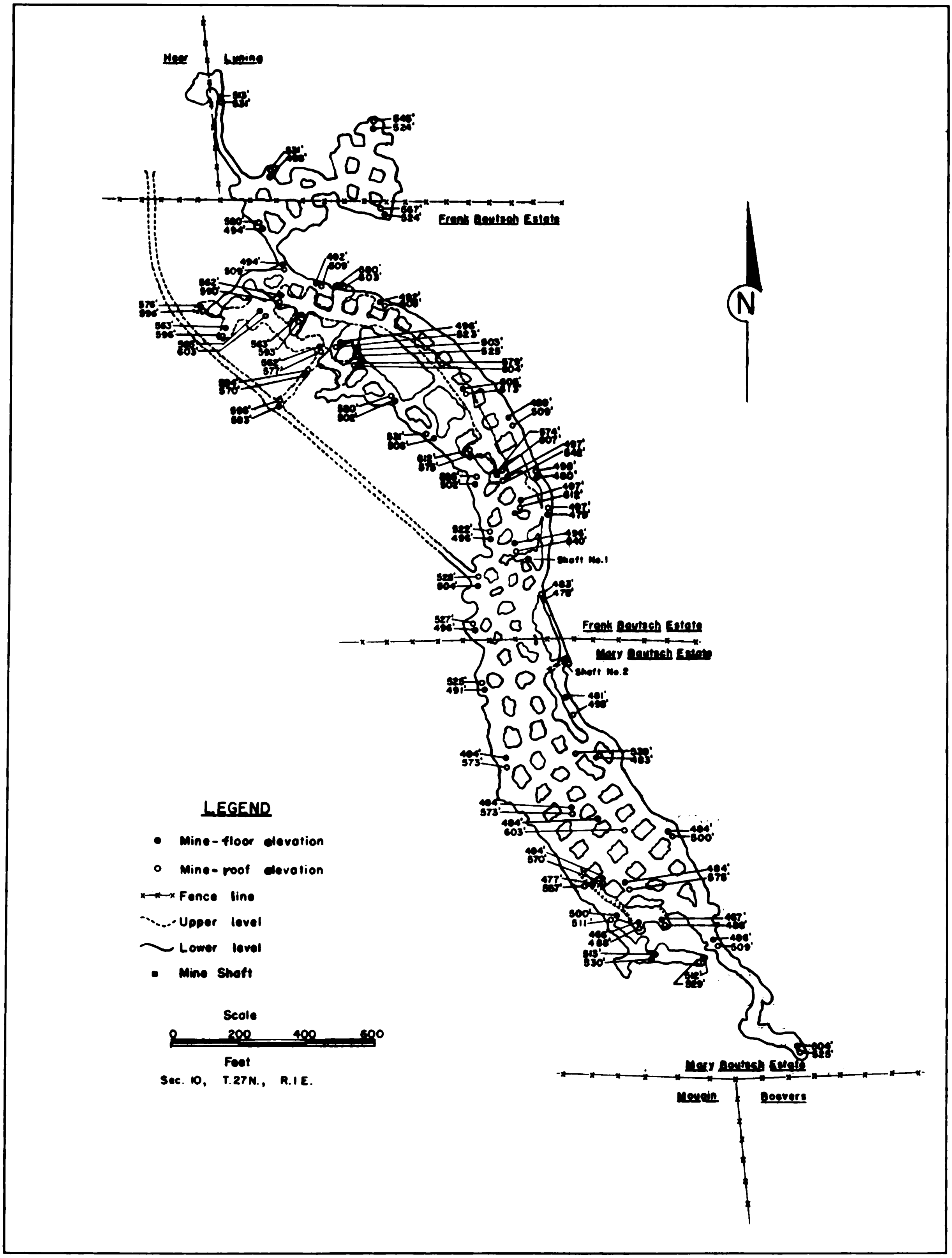

Figure 2. - Bautsch mine map.

HISTORY OF MINE

Mining was begun by the company in 1944, first on the Heer ore body and shortly thereafter on the Bautsch. The potential worth of the property could be judged at the time only by the result of a wartime drilling project conducted by the Federal Bureau of Mines, which indicated a small zinc-lead deposit of roughly 400,000 tons, based largely on drilling at the Heer property. However, the Bautsch ore body had been discovered and drilled in part by the Bureau of Mines the previous year, and a good ore potential was indicated on that property. Because of the well-advanced exploration, the initial operation was at the Heer, and consequently the mill was located adjacent to the Gray mine (Heer) hoisting shaft.

Established mining practices in the district were initially followed at both the Heer and Bautsch deposits. Small vertical shafts were sunk (200 to 300 feet deep), and the ore was hoisted in 1,200-pound-capacity buckets or cans. Special nonspinning hoisting cables were used as the loaded buckets were picked up from the mine platform cars. The stopes or working faces were opened directly from the shafts, and light narrow-gage tracks were laid for tramming. Hand tramming was used for short distances, and electric haulage was used in main haulage drifts.

Ore was mined in open stopes with irregularly-placed pillars of large blocks of the lower grade ore. Mining was done by breast stoping with a top heading about 6 feet in height driven in advance and successive benches taken out down to the floor. Drilling machines were mounted on columns in the top headings and on tripods on the benches. Loading was done either by small, air-driven shovel loaders mounted on wheels to engage the mine tracks or by slushers.

After the Bautsch ore body was developed, the problem was raised whether (1) to move the existing mill to the Bautsch; (2) to construct a second mill at the Bautsch; or (3) to maintain the original mill but enlarge its capacity and to move all ore, wherever mined, to it. The location of other ore bodies to be mined at a later date, and consideration of capital expenditures required resulted in the decision to enlarge the capacity of the mill in its original location and improve the method of transporting ore to it. The latter was accomplished by driving an inclined adit from the surface to the bottom of each ore body suitable for diesel-truck haulage. The adits were large enough to allow passage of all mechanical equipment required underground.

The Bautsch adit was completed in June 1949 at a total cost of roughly $60,000, or about $35.50 per foot, exclusive of capital outlay for equipment which was used in subsequent mining.

An adit was driven at the Black Jack mine to develop the reserves of low-grade ore left there particularly in the north end of the mine. The Black Jack was discovered in 1854 and was the most important of the famous Galena district mines of the Civil War era. Before being leased by Tri-State Zinc, Inc., it was last operated in 1926; to that date nearly 2,000,000 tons of ore was reported to have been mined.

The Pittsburgh ore body, also shown in figure 1, was reported to have produced 6 percent zinc ore in 1914 and 1915, when production included ore from both "pitches" and "flats," but when closed in 1916, ore produced entirely from the "core ground" averaged 3 percent zinc. "Core ground" is the term used locally for material between the reverse faults or two zones of pitches.

Production of zinc-lead ore by Tri-State Zinc, Inc., from this group of properties is given in table 1.

TABLE 1. - Gray mine production total to June 30, 1955

	Short tons
Tonnage milled, dried ore	2,249,162
Zinc concentrates, 62.70 percent zinc	117,335
Lead concentrates, 75.70 percent lead	13,454

DESCRIPTION OF DEPOSITS

Geology

To better understand the mode of occurrence of ore bodies and the physical characteristics of strata that influence mining methods, a generalized stratigraphic section (fig. 3) is given, and the geology of the area is discussed briefly.

Most of the Upper Mississippi Valley lead-zinc district lies within the Driftless area, but glaciers of pre-Wisconsin age crossed its borders in certain places and are represented by small remnants of drift. Pleistocene bench and terrace gravels, sands, and clays are common in the valleys of the principal rivers. Deposits of interglacial loess of pre-Wisconsin age cap the bluffs extending in a belt several miles in width along both sides of the Mississippi River.

In the local area under discussion, the Pleistocene is represented generally by 5 to 35 feet of loess. In a few places up to 30 feet of valley filling composed of gravel, sand, and clay has been encountered by drilling to a total depth of 65 feet in unconsolidated overburden.

Commercial lead-zinc deposits in the Upper Mississippi Valley district occur in the Galena, Decorah, and Platteville formations, composed mostly of dolomite, although they include some limestone and shale, all of Middle Ordovician age. These formations crop out or constitute bedrock in a large part of the Upper Mississippi Valley district. In the productive part of the district in Illinois the bedrock is largely the Galena formation. However the slopes of the higher hills are made up of Maquoketa shale of late Ordovician time, and in some instances such hills are capped with dolomite of Early Silurian age. In the plateau; which rises near the southern border of the district to the south of the Bautsch ore body, overlaps the southeastern end of the Bautsch ore body, and extends northeastward; the Maquoketa shale is overlain by Lower Silurian dolomite. Outcrops of Lower Silurian dolomite, as well as Maquoketa shale, occur along a deeply incised northward-facing escarpment, which delimits the cuesta.

A small area of the basal member of the Decorah formation is exposed along the Galena River. This member and the uppermost member of the Platteville formation are well exposed in a bluff on the southeast side of Galena River near the center of sec. 34, T. 29 N., R. 1 E.

Largely owing to the differences in surface elevation, the depth below surface for the Bautsch ore body varies from about 150 feet at the northwestern end to about 500 feet at the southeastern end.

Silurian	Lower	Dolomite		190'	Dolomite, buff, cherty. Dolomite, light gray, shaly.
Ordovician	Upper	Maquoketa shale		130'±	Shale, blue green, with thin limestone layers. Phosphatic fossil zone at base.
	Middle	Galena dolomite	Dubuque shaly member	33'	Dolomite, yellow, thin bedded, shaly.
			Stewartville massive member	80'	Dolomite, buff, thick bedded. Receptaculites in lower part.
			Prosser cherty member	110'	Dolomite, gray buff, cherty. Receptaculites near base.
		Decorah formation	Ion dolomite member	40'±	Dolomite, gray, argillaceous. Limestone, pink, and carbonaceous shale - "oil rock." Shale, light green.
			Guttenberg limestone member		
			Spechts Ferry shale member		
		Platteville formation	Quimbys Mill member	60'±	Limestone, pink, and carbonaceous shale - "glass rock." Limestone, gray, thin bedded. Dolomite, gray buff, thick bedded. Shale, light green, sandy.
			McGregor limestone member		
			Pecatonica dolomite member		
			Glenwood shale member		
		St. Peter sandstone		70'±	Sandstone, white to brown.
	Lower	Prairie Du Chien group	Shakopee dolomite	50-75'	Dolomite, gray, locally cherty.
			New Richmond sandstone	0-25'	Sandstone, white lenses.
			Oneota dolomite	185'±	Dolomite, gray, locally cherty, shaly, and sandy.
Cambrian	Upper	Trempealeau formation	Jordan sandstone member	30'±	Sandstone.
			St. Lawrence member	125'	Sandstone and dolomite.
		Franconia sandstone		115'	Sandstone.

Figure 3. - Generalized stratigraphic section of the Upper Mississippi Valley lead-zinc district.

Type of Deposit

The commercial ore minerals are sphalerite and galena, with accompanying pyrite, marcasite, and considerable vein calcite. The major ore deposits are classified as the "pitch-and-flat" type. In this terminology a pitch is a mineralized reverse fault, and a flat is a mineralized bedding-plane fault or a vein in an opened bedding plane. Bedding-plane faults occur in the incompetent uppermost Platteville and lower Decorah strata. The reverse faults curve upward at low angles from these bedding-plane faults, steepening to about 45 degrees in the overlying beds. Reverse faults occur commonly in parallel groups that, in this area, are associated with narrow synclinal troughs. The reverse faults commonly form the outside boundaries of linear deposits varying greatly in size. However, outlying tabular ore extensions are common at the ends of major ore bodies where the group of reverse faults tend to merge and terminate.

Another type of ore deposit occurs in a joint-controlled system of vertical fractures, to which the term "gash-vein deposit" has been applied. All the rock formations contain vertical and inclined joints, the former being particularly well developed in the upper noncherty members of the Galena dolomite; it is the main structural characteristic of gash-vein deposits. Lead ore is the main product of these deposits, but zinc ore also is present in many of them, particularly at depth. The galena occurs as isolated crystals or clusters in a matrix of vuggy dolomite or dolomite sand and in narrow gashlike veinlets commonly less than 1 inch thick. Podlike masses of ore and rock several feet wide also are found in leached rock at favorable stratigraphic horizons along these joints. The inclined joints commonly are tight and in many places are in sets of closely spaced parallel fractures, which are probably incipient reverse faults. As an example, the Heer ore body presents a mineralized, closely spaced, vertical joint pattern between tight inclined joints or "dead pitches."

The Geological Survey[5/] statement in regard to ore origin is as follows: "The ore occurs in the fault zones as vein fillings and replacement veins along fractures and bedding planes; as cavity fillings in solution and tectonic breccias; and as disseminations formed by replacement and impregnation of favorable beds by poikilitic crystals of sulfides, particularly the shaly residuum of altered limestone strata."

Localization of mineralization by these factors resulted in a most irregular distribution of values. In the Bautsch deposit the higher grade ore occurs as vein types along steeply dipping fractures and in flat beds or seams joining or lying within the outside fractures, and as both breccia and disseminated types occurring irregularly within the area formed by the outer fracturing and between the irregularly placed horizontal seams. The roof is irregular, in extreme instances rising to a maximum of over 125 feet above the haulage level.

Physical Characteristics

The mine floor is determined by physical characteristics of the strata, as well as by mineralization. At the base of the Decorah formation is the Spechts Ferry shale member, locally known as the clay bed. It averages 2 or 3 feet in thickness. Underlying it is the Quimbys Mill member, or "glass rock," 3 to 14 feet in thickness.

[5/] Heyl, Allen V., Lyons, Erwin J., Agnew, Allen F., and Behre, Charles H., Jr., Zinc-Lead-Copper Resources and General Geology of the Upper Mississippi Valley District: Geol. Survey Bull. 1015-G, 1955, p. 235.

The clay bed would neither provide a suitable base for truck operation as it becomes soft when wetted nor provide a stable base for pillars of considerable height. Therefore, the haulage level was opened with several feet of the Guttenberg limestone member, or "oil rock," left intact below the mine floor. It has been stated that the limestone in this member was particularly susceptible to solution, and the stratum was favorable to disseminations. In the Bautsch deposit, the Guttenberg member is 4 to 10 feet thick, somewhat thinner than the normal 12 to 13 feet in the district. However, drilling apparently indicates that it is mineralized locally. That is, mineralization in "oil rock" is rather consistent along the toe of pitches, where the member is usually thinner, in places consisting of only the shaly residuum of altered limestone strata. Elsewhere the Guttenberg member rapidly attains a more nearly normal thickness and becomes sparsely mineralized. The underlying Spechts Ferry shale member is variable lithologically; the green, fossiliferous shale and thin, greenish limestones interfinger; near its base is a thin bentonite. It is considered likely that mineralization in "glass rock" will be consistent also below the toe of pitch areas in the Bautsch mine. Hence, it may be said that sporadic mineralization seems to be the condition for all three geologic members underlying the mine floor.

An exception in the stratigraphic position of the mine floor may be noted on the mine map at the southeastern end of the deposit. Three feet of the McGregor limestone and the overlying three members averaged 14.89 percent zinc in drill hole USDD 28. Ore indicated in this hole probably was mined in the workings that were carried below normal grade.

The district as a whole has been gently flexed, and folds of three orders of magnitude are recognized. The faulting mentioned above is related to the intermediate and small folds. The regional dip is about 17 feet to the mile, and folding is in the nature of low, broad undulations. The limbs of the folds rarely have dips greater than 15 degrees.

The limiting grade in estimating reserves is 3 percent zinc, and a factor of 12.5 cubic feet per ton of ore in place is used. The mineable deposits are estimated to average 4.0 percent zinc, and, as a rule, a few tenths percent lead. The average grade of mill feed largely depends on economic conditions. The mining problem, in respect to the Bautsch deposit, may be stated as one involving mining on a large enough scale to economically recover low-grade ore in a deposit several thousand feet in length of an average 200 feet in width and 60 feet in height, with an irregular roof in places 125 feet above the mine floor. A successful operation has been achieved by room-and-pillar open-stope mining in the wide and high portion of the ore body and by breast stoping elsewhere.

EXPLORATION

The initial Bureau of Mines exploratory work consisted of a churn-drilling campaign followed by enough angle core drilling to substantiate the results obtained in churn-drill holes.[6] The angle holes were restricted to the southeastern part of the Bautsch deposit where the overlapping Silurian dolomite greatly increased the depth of overburden. The Tri-State Zinc, Inc., considers the churn drill as the main tool for exploratory drilling on the surface, but does some underground core drilling largely to establish stoping limits.

---

[6] Zinner, Paul, and Lincoln, Francis Church, Exploration of the Gray and Bautsch Lead and Zinc Deposits, Jo Daviess County, Ill.: Bureau of Mines Rept. of Investigations 3947, 1946, 28 pp.

DEVELOPMENT

Ore bodies were developed first by vertical shafts and later inclined adits for truck haulage were driven at the Bautsch and Black Jack deposits. One-level operation has been the usual practice; however, an exception in the north end of the Bautsch mine is described in the following section of this report.

Mining (Stoping)

The mining method employed in the Bautsch deposit is open stoping with pillar support. The mine map shows that irregularly spaced pillars were left in that portion of the mine first opened, and at the south end a fairly regular pattern of a room-and-pillar system of mining was followed.

The Bautsch ore body was developed in 1946 by two vertical shafts and mined by breast stoping in a series of benches to the full height of the ore body. The benches were advanced in steps, each higher bench leading the next one below by about 12 feet. After the face had been advanced enough to establish the desired number of benches, depending upon thickness of ore, the mining cycle employing this method was as follows: First, the bottom bench was drilled to a height of 16 feet with a 2-jib jumbo mounted on crawler-type tracks. The bench was blasted and broken ore distributed by a bulldozer to permit the crawler-mounted drill jumbo to negotiate the grade and drill the second bench from the muckpile. These operations were repeated until the top bench had been drilled and shot. The entire muckpile was then loaded by a 1/2-yard boom-type electric shovel into 6-yard Koehring Dumptors for haulage to the shaft.

At present, breast stoping is restricted to the comparatively low and narrow parts of the main ore body and to the ore extensions in flat-lying ore-bearing strata in which disseminated ore is the rule. Development drifts, 14 by 17 feet in cross section, are driven as access drifts to open up new stopes or to the outlying ore-bearing zones. In these smaller openings muck is loaded into trucks by an Eimco Rocker shovel, both 104 and 105 models being used. Haulage is herein described under the heading "Underground Transportation."

Room-and-Pillar Mining

The room-and-pillar system of mining the Bautsch ore deposit consists of undercutting the entire area to be stoped on the haulage level by drifts and crosscuts 40 feet wide by 16 feet high. As nearly as the irregular shape of the ore body permits, the drifts are driven on 80-foot centers. In the subsequent mining this provides access to a stope from both ends and permits loading at one end of the stope while drilling and blasting operations are conducted from the top of the muckpile, with access to the later operations at the other end of the stope.

Excess broken ore is loaded from the end of the muckpile in longitudinal stopes, or from various side points when transverse stopes are being advanced. Since the broken ore accumulates as a support for men and equipment and means for removal of excess broken ore has been provided, the method is locally called modified shrinkage stoping.

After undercutting is well advanced, overhead stoping is carried on in a sequence of steps illustrated in figure 4. Incline slices are advanced about 8 feet in the back by drilling holes inclined 60° from the horizontal to a depth of 10 feet. A D-7 Caterpillar tractor builds a road on the muckpile for the drill

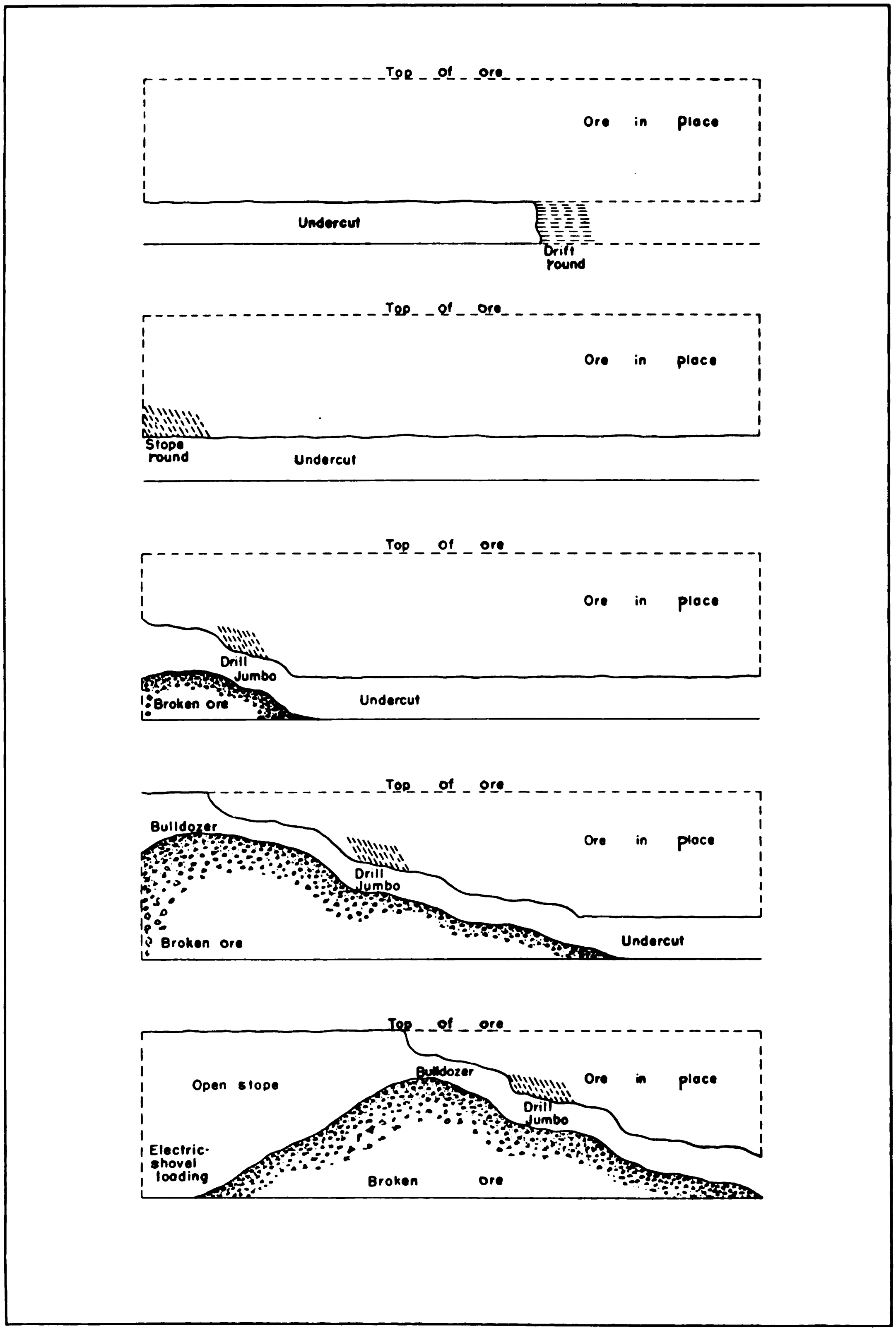

Figure 4. - Sequence of steps in room-and-pillar open stoping.

jumbo, maintains a 14- to 18-foot working space in the stope, and pushes the excess of broken ore over the brink of the pile. The maximum grades of about 30 percent require a crawler-mounted type of drill jumbo and powder-loading machine.

This method of stoping has the advantages of large-scale loading, drilling, and blasting operations, the first two of which may be carried on independently of each other. It necessitates carrying the stope up to a stratum that will provide a safe back. That is, grade of ore alone cannot determine the height to which a stope must be carried. For example, after an area in the north half of the ore body had been undercut it was found that the ore was too soft and too fractured to provide a safe back for this method. Subsequently a crosscut was driven from midway in the adit to the area and the ore was mined about 50 feet above the undercut. The back of the upper breast stopes is in barren ground and is strong enough to permit safe working conditions should it be desirable to mine the material between the upper and lower workings.

Mine Organization

Mining is on a 2-shift, 6-day-week basis, from 7:00 a.m. to 3:30 p.m. and from 7:00 p.m. to 3:30 a.m. All drilling and blasting are done on day shift, loading and hauling on both shifts.

The mining crew consists of the following:

Mine superintendent	1
Foremen	2
Jumbo operators (drillers)	8
Diamond drillers	2
Shovel operators	4
Truck drivers	4
Bulldozer operator	1
Powdermen	2
Compressorman	1
Maintenancemen (shop)	3
Total	28

The diamond drillers are employed when needed on roof scaling and secondary blasting. Two shovels and three trucks are employed each shift on loading and haulage. One of the shovel operators loads and drives one of the trucks. Maintenancemen generally work in the shop on surface; however, minor repairs may be done in the underground station provided for such work.

Drilling and Blasting

Drilling equipment consists of four 2-jib jumbos mounting either 3- or 3-1/2-inch drills (DA 30 or DA 35 I-R). One is mounted on crawler-type tracks and is driven by a compressed-air motor for use in development headings. The other three are diesel-powered, crawler-type, HD 5 Allis-Chalmers end loader tractors, modified at the mine shop to carry two 3-1/2-inch drills in place of the loading scoop or bucket. The drill steel used is 1-1/4-inch round steel, with 4-point detachable bits. The gage of the bits is 2 inches at the start, and one sharpening is the rule to 1-3/4-inch gage. Occasionally regrinding to 1-5/8-inch gage may be done. Average footage drilled per bit is 100 feet.

In undercutting of stopes a 38-hole V-cut is drilled to a depth of 12 feet (fig. 5). In overhead stoping, 10-foot holes are drilled into the back on an angle of 60° from the horizontal. Holes are drilled in straight lines spaced on 5-foot centers. Two men operate each jumbo. Adjustable floodlights mounted on a tripod aid in the efficiency of the work. An 800-cubic-foot-per-minute compressor, located on surface, and a portable 360-cubic-foot compressor, located underground, provide compressed air for drilling. Compressed-air transmission is through a 4-inch pipeline installed down one of the shafts and throughout different sections of the underground workings as progress of mining requires. Long header hoses are used at the drill jumbos for both air and water.

Two powdermen comprise the blasting crew. Explosives are taken underground each day from magazines on the surface. They are transported from a central station underground in the bucket of the HD-5 Allis-Chalmers front-end loader used in blasting operations in the stopes. Loading of the holes and the wiring of the round for stope blasting is done with one man standing in the bucket while the other maneuvers the machine. Atlas Gelodyn No. 1, a 60-percent-strength dynamite, is used in 1-1/2- by 6-inch cartridges for all blasting except blockholing, which is done with Gelodyn No. 2 powder. Regular delay electric caps 0 to 10 are available for making the detonators. Caps are shot by a 110-volt a. c. current. A maximum of 60 holes may be shot in one round. In overhead stoping all holes in a row except the end holes are shot together, starting the blast with the row nearest the open face and shooting each adjacent row at intervals by use of proper delay caps. The end holes next to pillars or solid ground are shot last.

Overall powder consumption, which includes development drifting, breast stoping, and overhead stoping, is 0.77 pound per ton of broken ore.

Ore Handling in Stope

In open-stope room-and-pillar mining, as well as in the multibench breast stoping, the bulldozer is an essential tool contributing to the success of the method of mining. The bulldozer builds a rough roadway on the broken ore pile, limiting grades to a maximum that can be negotiated by crawler-type equipment. It also pushes excess broken ore over the brink of the muckpile for immediate loading on the haulage level. Trucks are loaded by a 1/2-yard, boom-type, electric shovel; operating space required for a shovel of this type is 25 feet in width and 14 feet in height.

The back is barred down after blasting, and, except as noted herein, stopes are maintained in a safe condition for an extended period without artificial support. A limited amount of blockholing is required in the stope but much less than would be required if the ore were moved through ore pockets, chutes, and skips.

Underground Transportation

Diesel-truck haulage from underground working faces and stope loading locations to a truck dump hopper at the mill is now the practice. Access to the Bautsch mine is through an adit 12 by 17 feet in cross section and 1,700 feet in length, which was driven on a 10-percent incline. The portal of the adit is 2,500 feet from the mill.

Two types of trucks are used - the 6-yard Koehring Dumptor and the LeTourneau-Westinghouse Tournapull Rear-Dump. The Koehring Dumptor, with a 5-1/4-yard body (struck measure), is generally loaded with 10 to 10-1/2 tons of ore. The Tournapull Rear-Dump is loaded with about 15 tons of ore.

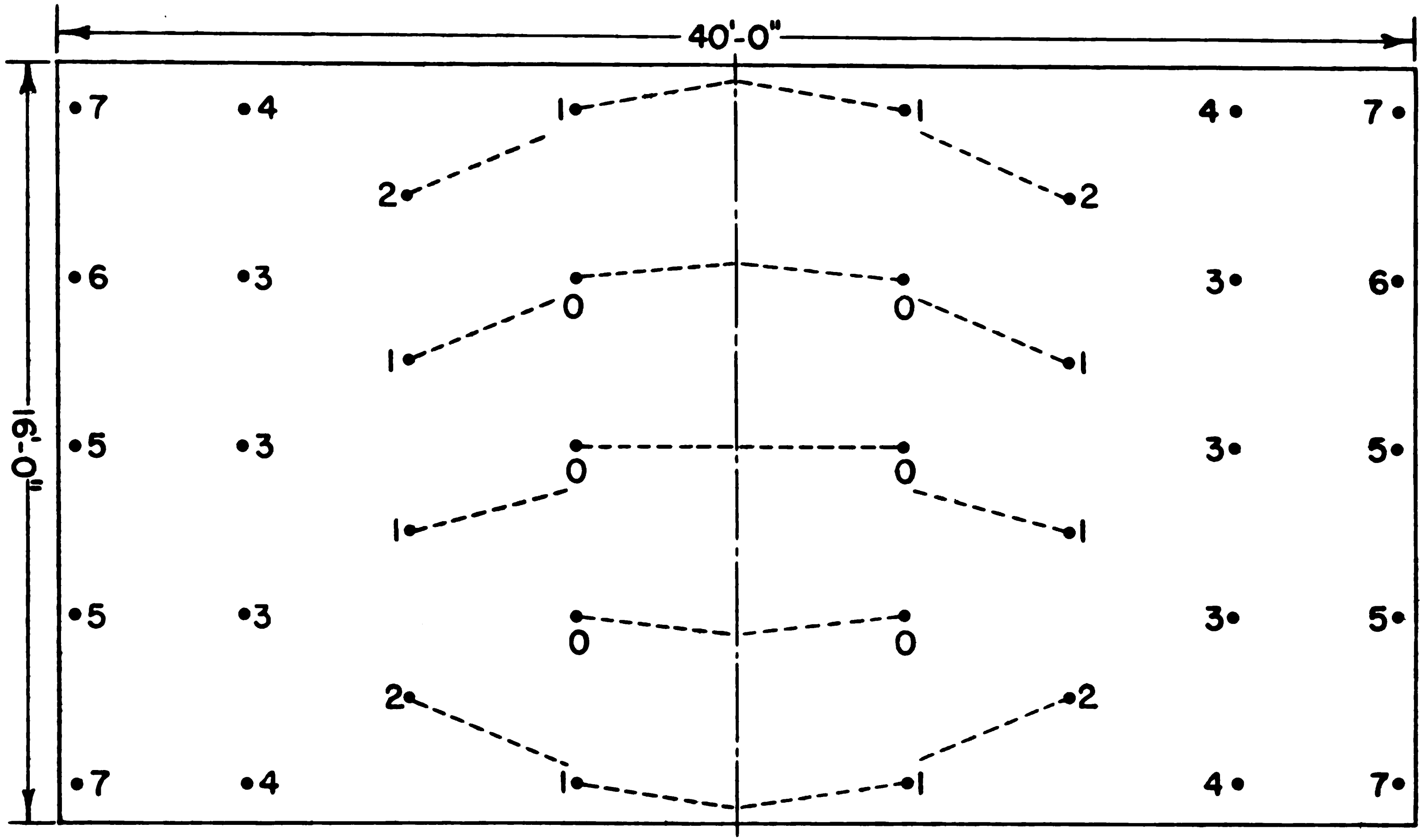

Figure 5. - Standard 38-hole V-cut round.

The average hauling distance is 1.2 miles, of which 0.5 mile is on a grade of 10 percent. Dumptors are driven with the load of ore in front while traveling to the mill and with the empty box in the rear when returning to the mine. The Rear-Dumps are backed into position for dumping.

Before dumping the load of ore into the dump hopper at the mill, each driver stops and weighs his load on a platform scale. The driver observes and records the weight from the driver's seat.

Summary - Equipment, Power, and Supplies

The total number and type of main equipment items are as follows:

1 - 24,000-c. f. m., low-pressure type fan.
1 - 800-cubic-foot compressor.
1 - 360-cubic-foot compressor (portable).
1 - 6-inch centrifugal pump.
1 - 8-inch American turbine (deep-well type).
4 - two-jib drill jumbos, crawler-mounted.
1 - HD-5 Allis-Chalmers front-end loader.
1 - 104 Eimco Rocker Shovel.
1 - 105 Eimco Rocker Shovel.
2 - 1/2-yard Koehring electric shovels.
1 - 1/2-yard Bay City electric shovel.
5 - 6-yard Koehring Dumptors.
2 - LeTourneau-Westinghouse Tournapull Rear-Dumps.

Power is purchased from a public utility, transformed to 440 volts, and taken underground through a churn drill hole. The electric shovels operate on this voltage. Circuits at 110 volts are provided underground for lighting, signals, and blasting. Total electric power used in mining and milling during the fiscal year ended June 30, 1955, in which 305,181 short tons of ore was mined, was 4,970,400 kw.-hr.

VENTILATION

Mechanical ventilation is provided by a main fan on the surface near the No. 2 Bautsch shaft, through which 24,000 cubic feet per minute of fresh air is forced. Approximately 8,000 cubic feet per minute of fresh air is drawn through several exploration churn-drill holes by auxiliary portable blowers, which are moved at intervals to different churn-drill holes.

The adit is used as the upcast airway. Thus the exhaust fumes discharged during periods of maximum truck-engine laboring are prevented from entering the mine proper.

On the first diesel equipment used underground by Tri-State Zinc, Inc., a cylinder of oxygen was mounted on each machine, discharging into the exhaust stream. This practice is no longer followed, after tests of mine air proved it unnecessary. Frequent tests of the mine air by company officials and periodic tests by insurance-company and Illinois State Mines Department engineers have failed to find a concentration of carbon monoxide or oxides of nitrogen approaching the maximum allowable limits of 100 parts per million of carbon monoxide and 25 parts per million of oxides of nitrogen. To date, carbon monoxide content in the upcast adit has never exceeded 10 parts per million.

MINE DRAINAGE

Except for the occasional ponding of water which requires a small pump, water flows to the sump at No. 1 Bautsch shaft and is raised to the surface by a 6-inch centrifugal pump. This pump is rated at 1,500 g. p. m. at 300-foot head. Present pumping in the Bautsch mine averages about 900 g. p. m.

An 8-inch American turbine deep-well-type pump is provided as standby at the No. 1 Bautsch shaft.

APPENDIX I - COSTS AND PERFORMANCE

Summary of Costs

The tabulation in table 2 covers operating mining and milling costs at the Gray mine of Tri-State Zinc, Inc., for the fiscal year ended June 30, 1955. Costs do not cover management, mine-office, and miscellaneous general expenses, such as depreciation, depletion, taxes, and insurance (other than compensation and social security).

Costs are based on the tonnage of dried ore mined and milled. Two mining methods were employed - breast stoping and room-and-pillar open stoping, but costs are not broken down for the two methods. Current exploration and development costs are included.

Performance data are given in table 3, and a summary of costs, in units of labor, power, and supplies, is shown in table 4. The costs,in units of power and supplies, include both mining and milling operations, except for fuel that was used in mining.

TABLE 2. - Summary of costs, in dollars

Gray Mine Operation

Tons mined: 305,181 (short tons, on dried basis)	Period covered:	Fiscal year ended June 30, 1955
Mining		
Breaking		
Drilling		
Labor	0.1397	
Compressor	.0434	
Drill steel	.0188	
Repairs and supplies	.1045	
Miscellaneous	.0009	
Total drilling	.3073	
Blasting		
Labor	.0295	
Explosives	.1674	
Repairs and supplies	-	
Miscellaneous	-	
Total blasting	.1969	
Total breaking		0.5042

TABLE 2. - Summary of costs (in dollars) (Con.)

Gray Mine Operation

Tons mined: 305,181 (short tons, or dried basis)

Period covered: Fiscal year ended June 30, 1955

Loading			
End loader (56,370 tons)			
Labor	0.0573		
Power (diesel)	.0055		
Repairs and supplies	.1553		
Miscellaneous	.0010		
Total end loader	.2191		
Electric shovel (248,811 tons)			
Labor	.0524		
Power (electric)	.0048		
Repairs and supplies	.0433		
Powerline	.0103		
Miscellaneous	.0002		
Total electric shovel	.1110		
Total loading		0.1310	
Ore haulage			
Road			
Labor	.0021		
Power (diesel)	-		
Repairs and supplies	.0052		
Miscellaneous	-		
Total road	.0073		
Diesel truck			
Labor	.0965		
Power (diesel)	.0122		
Oxygen	-		
Repairs and supplies	.0678		
Miscellaneous	.0015		
Total diesel truck	.1780		
Total ore haulage		.1853	
Roof trimmer			
Labor	.0090		
Repairs and supplies	.0007		
Miscellaneous	-		
Total roof trimmer		.0097	
Development			
Labor	.0120		
Explosives	-		
Power and repairs	.0122		
Churn drilling and assaying	.0106		
Total development		.0348	
General mine			
Labor	.0987		
Mine ventilation and lights	.0294		
Repairs and supplies	.0126		
Miscellaneous	.0169		
Total general mine		.1576	
Total mining			1.0226

Original from THE OHIO STATE UNIVERSITY

TABLE 2. - Summary of costs, (in dollars) (Con.)

Gray Mine Operation

Tons mined: 305,181 (short tons, or dried basis)	Period covered:	Fiscal year ended June 30, 1955
Pumping		
Labor	0.0007	
Power (electric)	.0568	
Repairs and supplies	.0060	
Miscellaneous	-	
Total pumping		0.0635
Milling		
Labor	.3072	
Power (electric)	.1675	
Crushing	.0169	
Ball mill	.0291	
Reagents	.0930	
Repairs and supplies	.1109	
Assaying	.0036	
Water supply	.0317	
Pond	.0105	
Miscellaneous	.0144	
Total milling		.7848
Total mining, pumping and milling		1.8709

Performance Data

TABLE 3. - Output per drill-shift and per man-shift

Total tons mined	305,181	
Total drill shifts	2,304	
Average tons per drill shift		132.46
Total number mine man-shifts	8,431	
Average tons per man-shift		36.21

TABLE 4. - Summary of costs in units of labor, power, and supplies

Gray Mine

Tons mined: 305,181
(short tons, on dried basis)

Period: Fiscal year ended 6/30/55
Mining method: Room-and-pillar

Labor (man-hours per ton mined):	
Breaking (drilling, blasting, trimming, dev.)	0.084
Loading	.049
Haulage	.044
General (includes surface)	.044
Total labor (underground and surface)	.221
Average tons per man-shift	36.21
Labor percent of total cost	48.5
Power and supplies (mining and milling):	
Explosives lb. per ton	.771
Fuel, used in mining gal. per ton	.106
Total power kw.-hr. per ton	16.287
Other supplies in percent of total supplies and power	68.46
Power in percent and total supplies and power	29.89
Total supplies and power	1.65
Power and supplies in percent of total cost	44.74
Mining, percent of total cost of mining and milling	54.7

APPENDIX II - MILLING

The Gray mill was designed originally to handle 600 tons of ore per day; by revisions in both primary and secondary crushing and by adding a ball mill the capacity was subsequently raised to 850 tons per day. The mill is now treating approximately 1,050 tons per day with good recovery.

The ore is crushed to minus-7/16-inch in 3 stages and dewatered in an Esperanza-type drag-belt classifier. The classifier underflow is split at the center cells of an 8-cell, Cooley-type jig, each half of the feed being sent to 4 cells. The tailing, which comes off the fourth cell on each half of the jig, amounts to about 50 percent of the initial feed. The hutch product from the first 2 cells is cleaned further in a single-cell Cooley-type jig to yield a 70-percent lead concentrate. The tailing from the cleaner jig and the hutch products of cells 2 and 3 are ground to minus-48-mesh in 2 parallel ball mills in closed circuits with spiral classifiers. The classifier overflow is conditioned and passes to a 2-cell lead circuit, where a lead flotation concentrate is made. The tailing from the lead cells passes to a zinc conditioner and on to a 6-cell flotation circuit. Zinc concentrate from the cleaner cell of this circuit is filtered and stored for shipment. The flotation tailing is sampled and flows to the tailing pond. Zinc concentrate produced averages 62.6 percent zinc. Metallurgical recoveries approximate 90 percent.

A flowsheet of the mill is shown in figure 6, and detailed description of milling operations is not considered necessary.

Milling operations are on a 6-day week, 24 hours a day basis. Sixteen men are employed in the mill, as follows: A mill superintendent, 3 jig operators, 3 flotation operators, 5 crusher operators, 3 general laborers, and 1 maintenanceman. Three of the crushermen are employed in the secondary crushing unit. The other 2 men in this category operate the primary crusher which crushes on only 2 shifts a day.

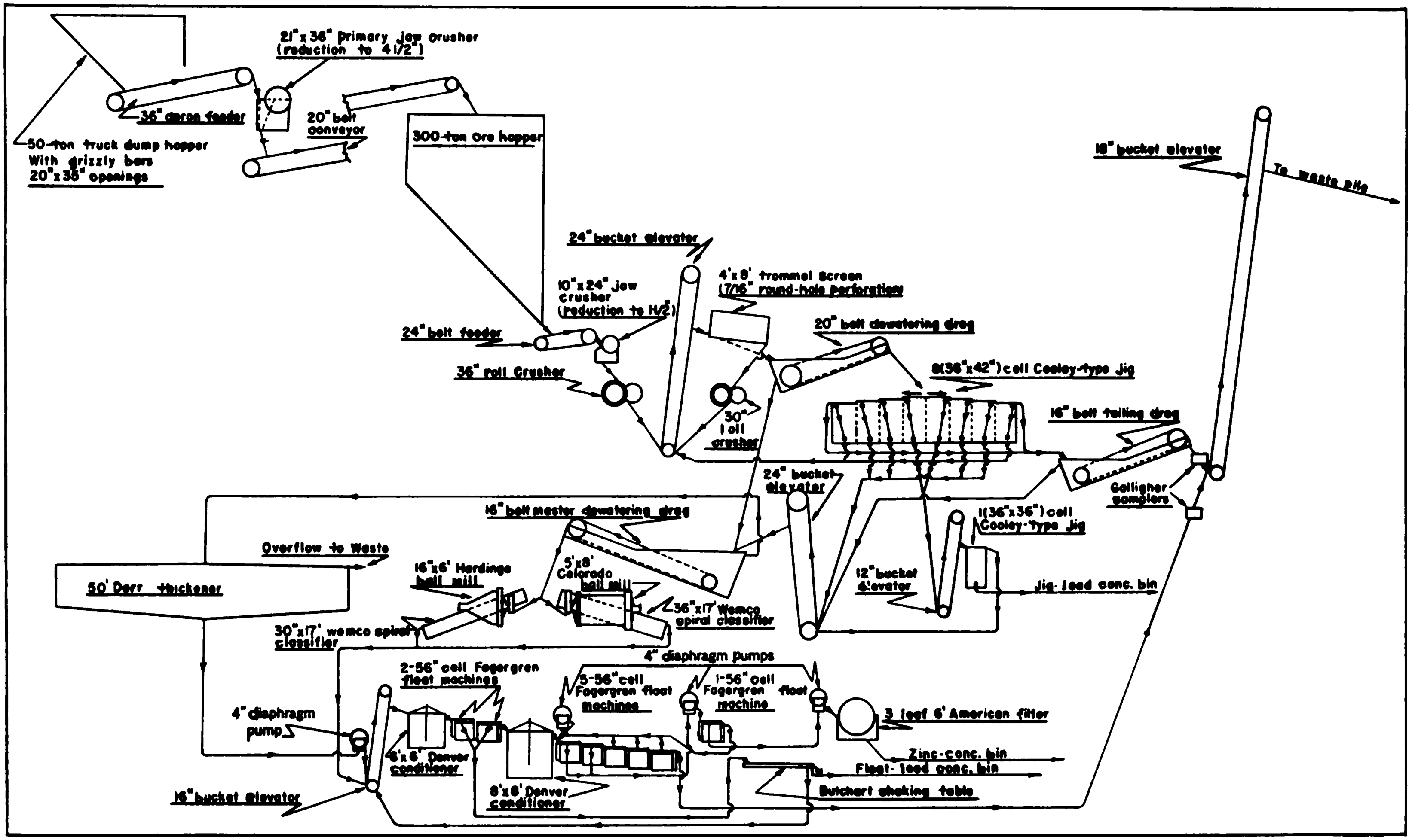
21"x 36" primary jaw crusher (reduction to 4 1/2")
36" apron feeder
20" belt conveyor
50-ton truck dump hopper With grizzly bars 20"x 35" openings
300-ton ore hopper
16" bucket elevator
To waste pile
24" bucket elevator
10"x 24" jaw crusher (reduction to 1 1/2")
4'x 8' trommel screen (7/16" round-hole perforation)
24" belt feeder
20" belt dewatering drag
36" roll Crusher
8(36"x 42") cell Cooley-type Jig
30" roll crusher
16" belt tailing drag
24" bucket elevator
Galligher samplers
16" belt master dewatering drag
1(36"x 36") cell Cooley-type Jig
Overflow to Waste
16'x 6' Hardinge ball mill
5'x 8' Colorado ball mill
12" bucket elevator
50' Dorr thickener
Jig-lead conc. bin
36"x 17' Wemco spiral classifier
30"x 17' wemco spiral classifier
4" diaphragm pumps
2-56" cell Fagergren float machines
5-56" cell Fagergren float machines
1-56" cell Fagergren float machine
4" diaphragm pump
3 leaf 6' American filter
6'x 6' Denver conditioner
Zinc-conc. bin
Float-lead conc. bin
8'x 8' Denver conditioner
Butchart shaking table
16" bucket elevator

Figure 6. - Flowsheet, Gray mill.

Original from THE OHIO STATE UNIVERSITY